THE INFLUENCE OF MICRO-NUTRIENT DEFICIENCY UPON THE WILTING RATE OF YOUNG WHEAT

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INTRODUCTION

Mineral nutrition is known to influence wilting in higher plants, but little accurate information is available concerning the effect that lack of essential minor elements have upon this process. It is quite clear that these elements play a very appreciable role in the water relation of plants, and both field (2, 3, 4, 7) and experimental investigations (1, 5, 9) have shown that deficiencies of these elements result in a decreased rate of transpiration.

Less is known on the influence of deficiencies upon wilting, and some of this information is apparently contradictory. As long ago as 1937, Willis and Piland (10) observed that in hot weather boron deficient romaine lettuce wilted very severely while plants grown on borax treated soil did not. Schütte (8) demonstrated experimentally that in the radish deficiency of boron, copper, manganese and zinc resulted in increased susceptibility to wilting. On the other hand, Leaf studying the influence of boron on tobacco (5) and Baker, Gauch and Dugger (1) working with snap-beans, sunflowers and tomatoes, found that deficiency of boron resulted in a *decreased* rate of desiccation in excised leaves. However, rate of desiccation is not necessarily synonymous with wilting. The latter workers observed that during periods of sudden heat marked wilting occurred in normal beans but none in the boron deficient ones. This apparently contradictory state of affairs has not been explained.

In this investigation, the influence of deficiencies of boron, copper, manganese and zinc upon the wilting rate of young wheat was investigated. Under South African conditions, deficient plants in the field are more prone to wilt than normal ones. An effort was made to assess wilting rates quantitatively and the experiments were conducted in autumn, winter and spring in an effort to observe if seasonal variations were of any significance.

Methods

The experimental plant used was a wheat *Triticum vulgare* 'VERNAL', which grew well in sand culture. The wheat was germinated in dishes of acid washed sand moistened with de-ionised water, and transplanted to pots of acid washed sand when 3·5 cm. tall, at the rate of 20 plants per pot. The seedlings were irrigated with a slightly modified Robbins' Solution (6) every two days. The control plants received all essential nutrient elements, while deficient plants received all essential elements except the one being investigated.

The following five treatments were used—

Control	Full nutrition
— B	Boron deficient
— Cu	Copper deficient
— Mn	Manganese deficient
— Zn	Zinc deficient

The plants were grown in an unheated glass-house, with 80 plants per treatment. The experiment was repeated three times, in April, in June and in September and the relevant data on temperature, relative humidity and evaporating power of the air was recorded.

Wilting was determined very simply. After 12 days, half the plants were removed from the sand with their rooting systems intact. The rest were removed and studied after 24 days. Three hours previous to their removal from the sand, the pots had been irrigated. All the plants used were turgid and completely normal in appearance. *No obvious visual signs of deficiency could be observed in any of the plants.* The entire plant was inserted into a small wire tripod 10 cm. high and completely exposed to the surrounding atmosphere. The time taken for the leaves to droop was recorded and this drooping of the leaves and stem was taken as the criterion of wilting. Plants were wilted in batches of 10 and the number of wilted plants was recorded every five minutes for 40 minutes. This made the results obtained readily amenable to statistical analysis.

Results

In spite of the fact that the method used to determine the rate of wilting appears to be rather subjective, it was found to yield very consistent results. There was very little variation within any one treatment, as the analysis of Mean Squares showed, and the results were consistent within the treatments at the 0·1% level. Again, the results obtained in autumn, winter and spring all gave similar results (in June no wilting tests were undertaken on 24 day old plants).

Table I gives the details of the wilting experiments. It is quite obvious that all the deficient plants wilt more rapidly than the controls and also that the rate of wilting is similar in all the treatments of the same age, irrespective of the time of the year at which they were performed.

TABLE I

Relationship between the length of time wheat plants have been exposed to wilting and the number of wilted plants in any given treatment. Each batch consisted of 40 plants (subdivided into four groups of 10 for statistical purposes) and was exposed for 40 minutes.
Columns A (April), B (June) and C (September) refer to the season of the year in which the experiment was conducted.

Time in Minutes	Control			−B			−Cu			−Mn			−Zn		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
12 DAY OLD WHEAT															
10	3	2	6	6	3	9	15	9	20	15	7	16	24	16	24
15	7	5	9	14	7	14	26	21	29	26	15	27	30	23	32
20	9	9	9	16	8	14	28	25	30	27	16	28	31	26	82
25	12	9	11	16	9	15	30	25	34	29	18	30	33	27	35
30	13	11	12	18	12	15	33	29	35	32	22	33	33	30	37
35	15	13	13	18	12	18	34	32	38	33	25	33	35	33	38
40	15	14	14	18	13	20	36	33	40	33	26	36	36	33	39
24 DAY OLD WHEAT															
10	7	—	9	19	—	17	10	—	18	6	—	12	12	—	18
15	11	—	15	27	—	33	20	—	28	14	—	21	20	—	29
20	11	—	15	28	—	33	22	—	29	16	—	24	23	—	29
25	13	—	17	32	—	34	29	—	31	20	—	25	27	—	31
30	16	—	19	34	—	35	30	—	33	24	—	28	30	—	32
35	17	—	21	35	—	37	33	—	36	27	—	32	33	—	33
40	18	—	22	37	—	38	36	—	37	28	—	33	37	—	35

A — April Temperature 29°C, evaporating power of the air 0·46 kg.$H_2O/m^2/hr$.
B — June Temperature 24°C, evaporating power of the air 0·24 kg.$H_2O/m^2/hr$.
C — September Temperature 30°C, evaporating power of the air 0·52 kg.$H_2O/m^2/hr$.

The difference between the percentage of wilted plants after 40 minutes in the controls and in deficient plants is highly significant. In 12 day old plants the level of significance is 0·1% for —Cu, —Mn and —Zn, while —B is 1·0% (except in June when bad weather disturbed the experiment). —Cu, —Mn and —Zn do not differ significantly from each other but do from —B. In 24 day old plants, all treatments differed from the controls at the 1·0% level, while —Mn differed from —B, —Cu, —Zn at the 5% level, the latter not differing significantly among themselves.

The graphs on Fig. I, in which percentage wilting is plotted against time, clearly depict the wilting rate of these plants. The rate of wilting in the control plants is much slower than that of the deficient material. In 12 day old wheat, the rate of wilting in the —B treatment is significantly slower than that in the other deficient treatments, yet in 24 day old plants —B shows the most rapid rate of wilting of all the plants. In these 24 day old plants the pattern of —Mn

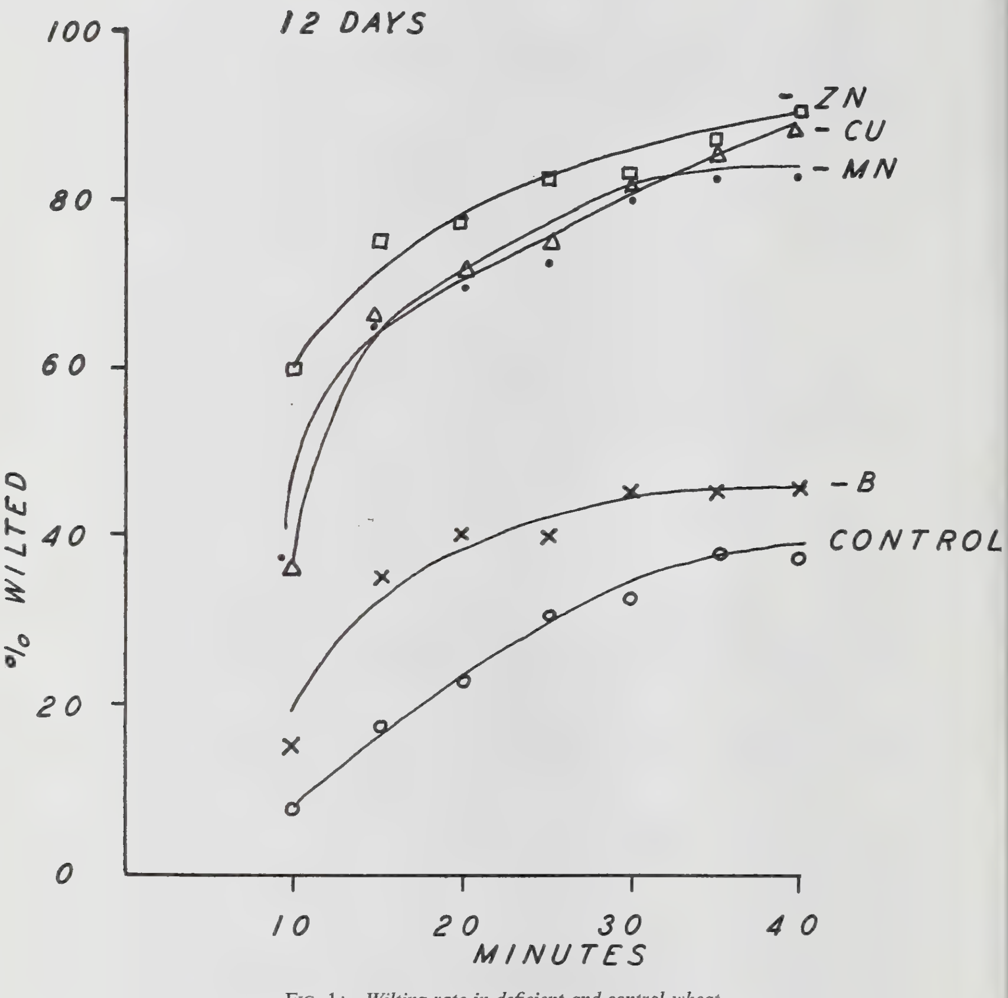

FIG. 1A. *Wilting rate in deficient and control wheat.*

The percentage of wilted plants is plotted against time in minutes. It is clear both in 12 and 24 day old plants that the wilting rate of the controls is the lowest of all the treatments, while the rate in deficient wheat is always significantly higher.

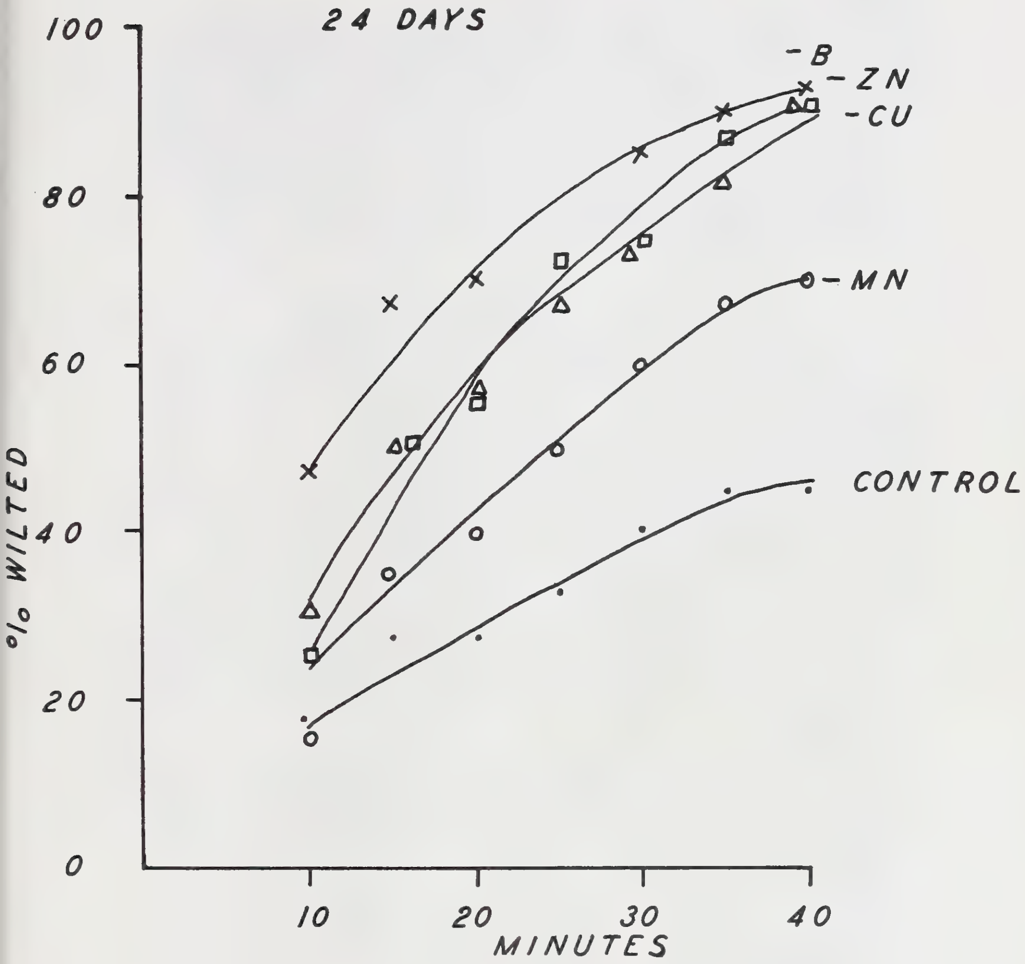

FIG. 1B. *Wilting rate in deficient and control wheat.*

The behaviour of boron deficient plants is particularly anomalous as at 12 days their rate of wilting is low yet at 24 days it is highest of all the treatments. The rate of wilting in manganese deficiency is also influenced by time but to a much smaller extent.

Data plotted was obtained from experiments conducted in April. Experiments conducted at other times gave similar results.

also changes and its wilting rate is slower than that of the other deficient treatments.

The behaviour of —B differs considerably from that of other treatments in that its influence upon the wilting rate of 12 day old plants is quite distinct from that upon 24 day old wheat. It is also anomalous in that the wilting curve is not a smooth one but frequently appears to be characterized by a series of steps, which is not the case in any of the other treatments. The consistency with which this jerky response occurs appears to preclude its being fortuitous and the design of the experiment and the number of plants used were adequate to ensure that it is a genuine response.

Discussion

This experiment clearly demonstrates that in young wheat, even before visual symptoms of deficiency are apparent, deficiencies of boron, copper, manganese and zinc increase proneness to wilting. This is in keeping with field observations made in South Africa. Previous experiments with radishes had shown a similar picture, (8). The anomalous behaviour of boron in this investigation, in which the wilting pattern of 12 day old wheat is quite distinct from that of 24 day old plants, is very hard to explain. Similar behaviour had previously been observed (8) but no significance had been attached to the observation. This marked alteration in behaviour with age, as well as the completely different nature of the wilting curve, appears to indicate that boron plays an unusual and, as yet, unexplained role in wilting and other aspects of water relations. As far as wilting is concerned, the behaviour of boron deficient wheat is quite distinct from the plants studied by Leaf (5) or Baker, Gauch and Duggar (1).

The results of this experiment are also of interest from another point of view, as they indicate some complex problems in water relations. Other investigations have shown that deficiency of trace elements results in a decreased rate of transpiration (1, 2, 3, 4, 5, 7, 9). Therefore, it seems likely that deficiencies either hamper the absorption or the conduction of water by the plant, as it is unlikely that increased proneness to wilting can be due to increased and excessive loss of water when the transpiration rate is decreased. In this context, it must be stressed that in young material like that used in this experiment, marked anatomical changes which may help to explain this state of affairs, have not yet taken place.

It is clear that further investigations must be undertaken to clarify our knowledge on the influence that deficiencies have upon the water relations of higher plants.

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